

## SELF-MONITORING RADIO NETWORK

### Field of the Invention

The invention relates generally to a radio network, and more particularly to a  
5 radio network capable of detecting the occurrence of malfunction in one of its constituent two-way radios.

### Background of the Invention

Radio networks are frequently deployed in commercial settings, such as retail  
10 stores, warehouses, or quick service restaurants. For example, a quick service restaurant may utilize a radio network to facilitate communication between a drive-through customer in a drive-through lane and an employee taking the customer's order. Such a radio network also permits the employees of the store to efficiently communicate with one another. In this context, the radio network is more commonly  
15 thought of as an "intercom system," with the two-way radios often taking the form of headsets, in which the microphone, speaker, and transceiver are affixed to a unit worn upon the employee's head. For the most part, such a communication scheme provides a relatively inexpensive and reliable form of communication for the employees.

The above-described scheme does possess one shortcoming of note, however.  
20 In the event that one of the two-way radios (i.e., one of the headsets) malfunctions, employees tend to set the malfunctioning unit aside in favor of a properly functioning unit. Oftentimes, no record is made of the fact that a particular unit has ceased to function. Over time, the number of cast-aside units grows, until the particular retail setting (e.g., quick service restaurant) suddenly and unexpectedly finds itself with an  
25 insufficient number of radios for proper operation of the store/restaurant. Then, only after being spurred on by a crisis, all of the malfunctioning units are serviced, and the store/restaurant is returned to operability.

As is made evident from the above discussion, there is a need for a scheme by which the silent and unobserved accumulation of malfunctioning radios may be

avoided. A desirable scheme would require the deployment of little additional hardware, require minimal re-design of existing components of radio networks, and would be relatively inexpensive to deploy.

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### Summary of the Invention

Against this backdrop, the present invention has been created. A method of identifying nonfunctional two-way radios from among a known group of two-way radios expected to be operating within a region may include establishing a corresponding window of time for each of the two-way radios expected to be operating within the region. For each of the established windows of time, a transmission from the corresponding radio is awaited. If, for a particular radio, no transmission is detected within its corresponding window of time, the absence of the transmission is recorded. Finally, if, for a particular radio, the number of times absence of transmission has been recorded exceeds a threshold, the particular radio is identified as nonfunctional.

According to another embodiment of the invention, a two-way radio may be improved so as to render its operability observable. Such a two-way radio may include an antenna for receiving and broadcasting transmissions. Additionally, it may include a transceiver unit coupled to the antenna. The transceiver unit modulates a carrier signal with a signal to be transmitted and recovers a baseband signal from a received transmission. The radio may also include a microprocessor coupled to the transceiver unit. The microprocessor is programmed to command a broadcast of a transmission containing a code identifying the radio, at a designated point in time. Prior to the broadcast of the transmission containing the identification code, a transmission protocol governing subsequent transmissions is known by the radio.

According to yet another embodiment of the invention, a wireless intercom system may include a first two-way radio fashioned as a headset. The system may also include a second two-way radio fashioned as a headset. Additionally, the system may include a repeater unit. Transmissions from the first and second two-way radio may occur upon a first carrier frequency. The first and second two-way radios may receive

transmissions carried upon a second carrier frequency. The repeater unit may receive transmission carried upon the first carrier frequency, and may broadcast transmissions upon the second carrier frequency, thereby enabling the first and second two-way radios to communicate. The repeater unit may establish a first window of time corresponding

5 to the first radio and a second window of time corresponding to the second radio. The repeater unit may await a transmission from the first radio during the first window of time, and may await a transmission from the second radio during the second window of time. The repeater unit may record absence of transmission from the first radio, if no transmission is received from the first radio during the first window of time. The

10 repeater unit may record absence of transmission from the second radio, if no transmission is received from the second radio during the second window of time. The repeater unit may identify the first radio as nonfunctional if the number of times absence of transmission by the first radio has been recorded exceeds a threshold. Finally, the repeater unit may identify the second radio as nonfunctional if the number

15 of times absence of transmission by the second radio has been recorded exceeds a threshold.

#### Brief Description of the Figures

Figure 1 depicts an embodiment of a radio network, in accordance with the

20 present invention.

Figure 2 depicts an embodiment of a two-way radio, in accordance with the present invention.

Figure 3 depicts a schematic block diagram of one embodiment of a base station and radio, in accordance with the present invention.

25 Figure 4 depicts a state transition diagram describing the behavior of the base station, in accordance with one embodiment of the present invention.

Figure 5 depicts a flowchart of a method of identifying nonfunctional radios within a radio network, in accordance with one embodiment of the present invention.

Figure 6 depicts a flowchart of a method for establishing a window of time for a particular radio within a radio network, in accordance with one embodiment of the present invention.

Figure 7 depicts a flowchart of another method for establishing a window of time for a particular radio within a radio network, in accordance with one embodiment of the present invention.

Figure 8 depicts a flowchart of yet another method for establishing a window of time for a particular radio within a radio network, in accordance with one embodiment of the present invention.

10 Figure 9 depicts a radio network, including auxiliary devices, in accordance with one embodiment of the present invention.

Figure 10 depicts a flowchart of a method for automating a service request, in accordance with one embodiment of the present invention.

15 Figure 11 depicts a flow chart of a method of initializing a radio, in accordance with one embodiment of the present invention.

#### Detailed Description of the Invention

A radio network may be made to observe and record inactivity on the part of radios within the network. Employing the assumption that prolonged inactivity of a 20 particular radio may indicate its nonfunctionality, the network may utilize a threshold, whereby a radio is deemed nonfunctional if it is inactive for a length of time exceeding the threshold.

Radio activity may be observed by a listening device. The listening device may establish a window of time during which it expects to receive a transmission from a 25 particular radio. If the window of time elapses without the listening device receiving a transmission from the particular radio, the absence of such a transmission is recorded. Subsequently, the listening device opens another window of time during which a transmission from the particular device is awaited. Once again, if the window of time elapses without a transmission from the particular radio, the omission is again recorded.

If the number of recorded absences of transmission exceeds a threshold, the particular radio is declared nonfunctional.

Optionally, the listening device may be made to automatically contact a repair service, and schedule the nonfunctional radio for service. In another optional 5 embodiment, the listening device may be made to receive alarm signals from auxiliary devices (such as an over-temperature sensor on a freezer). In response to an alarm signal from the auxiliary device, the listening device may contact an appropriate repair service.

The following disclosure describes the invention with reference to a radio 10 network in which a plurality of two-way radios communicate with one another via a repeater. Each two-way radio broadcasts upon a first frequency using frequency modulation (FM) transmission; each radio receives FM transmissions carried on a second frequency. A repeater is used to receive transmissions carried on the first frequency and rebroadcast those transmissions on the second frequency. The radio 15 communication is half-duplex, and no form of multiplexing is employed. Although the invention is described with reference to such a network, none of these features are critical to the invention. The invention is susceptible to deployment within a radio network employing any form of modulation and any form of multiplexing (including frequency domain multiplexing, time domain multiplexing, and code division multiple 20 access). Additionally, the invention may be deployed in a network employing full or half duplex communication. The invention need not be embodied within the repeater.

FIG. 1 depicts one embodiment of a radio network 100, in accordance with the present invention. As can be seen from FIG. 1, the radio network 100 includes a plurality of two-way radios 102 and a base station 104. None of the radios 102 25 communicate directly with one another. Instead, each of the radios 102 communicate to the base station 104, which, in turn, relays the communication to the other radios 102. Each of the two-way radios 102 transmits upon a first frequency,  $F_1$ ; each receives signals carried upon a second frequency,  $F_2$ . The base station 104 functions as a repeater 104, in that it receives the transmissions from the radios 102, carried on

frequency  $F_1$ , and re-broadcasts those transmissions on frequency  $F_2$ . Thus, the other radios **102** are able to receive transmissions by virtue of the function performed by the base station **104**. While a particular radio **102** is broadcasting, it is unable to receive a transmission (its communication is half duplex). Additionally, no form of multiplexing 5 is employed by the radio network **100**. Therefore, if two radios **102** transmit simultaneously, their transmissions interfere with each other.

The radio network **100** depicted in FIG. 1 is of the sort typically found in quick service restaurants, for instance. In this type of setting, each of the two-way radios **102** may be in the form of a headset. An exemplary headset **200** is depicted in FIG. 2. As 10 can be seen from FIG. 2, the microphone **202**, speaker **204**, and transceiver **206** are affixed to a unit worn upon an employee's head. Other configurations of two-way radios may also be used according to the present invention.

Returning the discussion to FIG. 1, it can be seen that the base station **104** is in communication with a drive through sign **108**. The communication between the sign 15 **108** and the base station **104**, which allows a drive-through customer to place an order, may or may not be wireless. The base station **104** is also in communication with a magnetic proximity loop **106**, buried beneath the pavement of the drive through lane. When a car passes over the magnetic proximity loop **106**, a signal is communicated to the base station **104**, and the base station **104** generates an alert tone to an employee 20 charged with the task of greeting and taking the order of the drive-through customer. In response to the alert tone, the employee typically greets the customer, and asks for the customer's order. Finally, the base station **104** may interface with a network, such as a telephone network **110**, as shown in FIG. 1.

FIG. 3 depicts a schematic block diagram of a two-way radio **102** and base 25 station **104**, in accordance with the present invention. The two-way radio **102** includes a transceiver **300**, which accomplishes the task of transmitting and receiving signals upon frequencies  $F_1$  and  $F_2$ , respectively. For purposes herein, the transceiver **300** is also thought to include the circuitry necessary for amplifying and producing an acoustic sound signal to the user of the radio **102**. Similarly, the transceiver **300** is thought to

contain the circuitry necessary to transduce a sound signal for transmission. A microprocessor 302 controls the transceiver 300. For example, the frequencies  $F_1$  and  $F_2$  may optionally be commanded by the microprocessor 302. The microprocessor 302 may also control other functions of the transceiver 300, such as volume control. The 5 microprocessor 302 is in communication with a memory device 304, which contains the firmware/software executed by the microprocessor 302. Finally, the microprocessor may be in communication with an infrared (IR) interface 306, which permits data communication with another IR transceiver, as discussed in more detail below. Another data interface may be substituted for the IR interface 306. For example, a cable-based 10 data interface, such as a data interface that operates via a serial port may be used in lieu of the IR interface 306. Except as disclosed herein, the design of the two-way radio 102, including the design of the transceiver 300, the microprocessor 302, the memory device 304, and the IR interface 306, is known in the art.

As can be seen from FIG. 3, the base station 104 also contains a transceiver 308, 15 a microprocessor 310, a memory device 312, and an IR interface 318, each of which functions in accord with the discussion related to the two-way radio 102. Once again, another data interface may be substituted for the IR interface 318. The base station 104 also possesses a display 314 and an input device 316. The display 314 presents 20 information to a user (e.g., an employee of a quick service restaurant). The display 314 may take on any suitable form, such as a liquid crystal display (LCD). The input device 316 permits a user to input information into the base station 104. The input device 316 may take on any suitable form, including, but not limited to, a keypad, a mouse, a trackball, a switch, a button, or a joystick. The display 314 and input device 316 may 25 be integrated into a single unit, as in the case of a touch-screen display. Finally, the base station 104 possesses a network interface 320, which permits the base station 104 to communicate with a network. The network interface may take the form of a network card (such as an ethernet card), or may take the form a phone modem for communication via a telephone network. The base stations in the prior art have not had display devices.

FIG. 4 depicts a state transition diagram, describing the functionality of the base station 104, as it relates to its task of identifying nonfunctional two-way radios 102 within the network 100. The base station 104 performs other functions, such as repeating a signal, which are known in the art and are not reflected in the state transition diagram of FIG. 4. The flow depicted by the state transition diagram is depicted in greater detail in FIGs. 5-8 and 10-11. The methods depicted in FIGs. 4, 5-8, and 10-11 may be embodied in firmware stored in the memory device 312 within the base station 104. Of course, one skilled in the art understands that the aforementioned methods may be embodied in the circuitry of an application-specific integrated circuit (ASIC), as well.

When first installed, the base station 104 is idle with respect to its task of identifying nonfunctional two-way radios 102. This lack of activity is depicted by initial installation/idle state 400. When the base station 104 is first installed in a location, and occasionally thereafter, an initialization process can be used to store, in the memory 312 of the base station 104, a list of identification codes of the two-way radios 102 used with the base station 104. If a new radio 102 is added to the system, the initialization process may be carried out with respect to that new radio 102. Upon the occurrence of an initialization signal, the base station 104 transitions from the idle state 400 to an initialization state 402. The initialization signal maybe instigated by establishing an IR communication link between the base station 104 and a two-way radio 102 (via the IR interfaces 306 and 318), which is discussed in greater detail below. The initialization signal may also be instigated in many other ways, such as by establishing a cable connection between a two-way radio 102 and the base station 104. As described above, in this situation, the two-way radio 102 and base station 104 include a data port (such as a serial port), instead of an IR interface 306 and 318. One purpose of the initialization process is for the base station 104 to communicate basic information needed by the two-way radio 102 for it to conduct communication (e.g., the base station may communicate information regarding the specific frequency values,  $F_1$  and  $F_2$ , used by the base station 104). Another purpose is for the two-way radio 102 to

communicate its identity to the base station 104. The two-way radio 102 communicates its serial number and an identification code uniquely identifying the radio 102. In response, the base station 104 transitions to a list entry state 404, and enters the serial number into a list of radios 102 expected to be communicating with the base station 5 104. The list may be stored as a data array in the memory device 312 of the base station 104. The unique identification code is also entered into a list, and is associated with the serial number. Thereafter, the base station 104 transitions into a monitor state 406.

As will be discussed in greater detail below, execution of the monitor state 406 involves establishing a window of time for each radio 102 entered in the 10 aforementioned list. During the window of time corresponding to a particular radio 102, the base station 104 expects to receive a transmission from that radio 102. Thus, throughout the time window, the base station 104 examines each transmission it receives, extracting an identification code embedded therein. If the identification code matches the one associated with the radio under test, the radio 102 is assumed to be 15 functional, and the base station 104 remains in the monitor state 406. If, however, no such transmission is received, the base station 104 transitions into the record absence state 408. In the record absence state 408, a variable representing the radio's number of absent transmissions is incremented. If the aforementioned variable does not exceed a threshold, the base station 104 transitions back to the monitor state 406, and the base 20 station 104 carries on its monitoring function. If, on the other hand, the variable exceeds the threshold, the base station 104 declares the radio nonfunctional, as shown in state 410. The base station 104 then returns to the monitor state 406, and resumes the monitoring function.

With respect to the state transition flow depicted in FIG. 4, it should be noted 25 that a transition from the monitor state 406 to the initialization state 402 is possible. This transition occurs in response to an initialization signal, which may be instigated by the establishment of an IR link between the base station 104 and a radio 102 to be monitored. If the radio 102 initiating the IR signal is a new radio, its identification code

is entered into the list of codes. Thus, it is possible to add, on the fly, a radio **102** to the list of radios to be monitored.

FIG. 5 depicts a more detailed process flow of the operation of the base station **104**. The process begins with window establishment operation **500**, during which the 5 base station **104** establishes a particular period during which it expects to receive a transmission from a particular radio **102**. Next, upon the arrival of the point in time at which the time window is to commence, the window is opened in operation **502**. During the pendency of the time window, the base station **104** monitors the 10 transmissions it receives, looking for a transmission from the radio under test, as depicted in operation **504**. When the point in time at which the window is to be terminated arrives, the window is closed, as shown in operation **506**. Several methods of carrying out operations **500-506** are depicted in greater detail in FIGs. 6-8.

After the close of the time window, it is determined whether a transmission had been received from the radio under test, as shown in operation **508**. The return 15 transmission from the radio **102** may contain the identification code as a sinusoid of a pre-defined frequency or as a pre-defined binary signal. If a transmission had been received, control returns to operation **500**, and the monitoring loop continues. If no transmission had been received, control flows to operation **510**, in which a variable representing the number of absent transmissions of the particular radio is incremented. 20 Next, in operation **512**, it is determined whether the aforementioned variable exceeds a threshold. If not, control returns to operation **500**, and the monitoring loop continues. If so, the radio is declared nonfunctional, as shown in operation **514**, and control returns to operation **500**.

FIG. 6 depicts one method by which operations **500-506** may be accomplished. 25 The method of FIG. 6 involves assigning a unique delay period to each radio **102**, as is shown in operation **600**. Operation **600** may be performed during the initialization state **402**, depicted in FIG. 4. Next, in operation **602**, the base station **104** transmits a query signal. A query signal is a signal that each radio **102** understands as a request for a return broadcast containing the unique identification code (discussed previously with

respect to the initialization state **402** of FIG. 4) assigned to the radio. This return broadcast is the means by which the base station **102** determines that the two-ways radios **102** remain functional. The query signal itself may be as simple as a pure tone at a pre-designated frequency carried atop the carrier frequency,  $F_2$ . Alternatively, the 5 query signal may consist of a binary signal carried atop the carrier frequency,  $F_2$ . In response to receiving the query signal, a two-way radio **102** responds with a transmission identifying itself. Importantly, per the scheme of FIG. 6, each radio **102** waits for an amount time equal to its uniquely assigned delay period, before broadcasting the return transmission. Thus, each of the radios **102** broadcasts its return 10 signal at a different point in time, thereby avoiding interference between the return broadcasts. Accordingly, after broadcast of the query signal, the base station **104** waits for a period of time equal to the delay period assigned to the particular radio **102** under test. Then, the window is opened, as shown in operation **606**. (During the pendency of the window of time, a response from the radio under test is awaited.) After waiting a 15 pre-defined period of time following the opening of the window, the window is closed, as shown in operations **608** and **610**, respectively.

FIG. 7 depicts another method by which operations **500-506** may be accomplished. The method of FIG. 7 commences with a transmission of a query signal directed toward a particular radio under test, as is shown in operation **700**. Given the 20 system of FIG. 1, the transmission will be broadcast carried upon Frequency  $F_2$ , and will thus be received by all of the two-way radios **102**. To direct the transmission to a particular radio **102**, the query signal contains a code identifying the particular radio under test. For example, the query signal may include the unique identification code (discussed previously with respect to the initialization state **402** of FIG. 4) associated 25 with the radio under test. Thus, although each radio **102** will receive the query signal transmission, the radio under test will respond (if functional), because the identification code embedded in the query transmission matches the identification code programmed into the radio under test. After transmission of the query signal, the time window is opened, as is depicted by operation **702**. (During the pendency of the window of time, a

response from the radio under test is awaited.) After waiting a pre-defined period of time following the opening of the window, the window is closed, as shown in operations **704** and **706**, respectively.

FIG. 8 depicts another method by which operations **500-506** may be accomplished. According to the method of FIG. 8, a window of time is opened periodically (e.g., once per day). During the pendency of the window, at least one transmission is expected from each radio **102**. For example, the two-way radios **102** may be programmed to transmit a signal identifying itself, during a power-up routine. Thus, assuming each radio **102** is powered up at least once per day, a transmission from each radio **102** should be received during the time window.

The method of FIG. 8 commences by opening a time window, as is shown in operation **800**. Optionally, this operation may be programmed to occur at a specific time of day (e.g., the window of time is opened at 6:30 AM, when the store/restaurant opens). Next, in operation **802**, the base station **104** waits a pre-designated amount of time, during which it expects to receive a transmission from each of the two-way radios **102** entered in its list. The period for which the time window pends may optionally correspond with the hours of the store/restaurant. For example, if the store/restaurant opens at 6:00AM and closes at 10:00 PM, the window of time may commence at 6:00AM and pend for 16 hours, until the arrival of 10:00 PM. Finally, as shown in operation **804**, the window of time is closed.

With respect to the methods of FIGS. **6**, **7**, and **8**, it should be noted that the two-way radios **102** may possess software, stored in memory device **304**, that causes the radio to respond to a query signal with a signal containing the unique identification code (also stored in the memory device **304**). The response may be transmitted a single time. Alternatively, the response may be transmitted more than once (e.g., four times), preferably at irregular intervals, so as to reduce the vulnerability to interference stemming from a periodic source (e.g., a 60 Hz. signal from an electrical line).

FIG. 9 depicts an embodiment of a radio network **101** that includes auxiliary devices **900**. The auxiliary devices **900** are other forms of equipment that possess

sensors which produce an alarm signal in response to the occurrence of a designated event. The identity of the auxiliary devices 900 vary based upon the setting in which the radio network 100 is deployed. If deployed in a restaurant setting, the auxiliary devices 900 may include a freezer with an over-temperature sensor, a storage facility for 5 meat with a humidity sensor, a circuit breaker box with an electrical current sensor, or a refrigerator with a water sensor. Each of these forms of auxiliary devices 900 (including the sensors) is known in the art. The base station 104 may receive the alarm signals from the auxiliary devices 900, thus eliminating the need for a controller corresponding to each auxiliary device 900. As with the communication between the 10 base station 104 and the drive-through sign 108, the communication between the base station 104 and the auxiliary devices 900 may or may not be wireless. The radio network 101 also includes two-way radios 102 and a telephone network 110.

In response to the alarm signal from the auxiliary devices 900, or in response to having declared a particular radio 102 nonfunctional, the base station 104 may be 15 programmed to execute the method depicted in FIG. 10. The method of FIG. 10 may be appended to the method of FIG. 5. In response to an alarm signal from an auxiliary device, or in response to a radio 102 being declared nonfunctional, an alert is presented on the display 314 of the base station 104. For example, the display may present a message reading "Radio serial number ##### appears to have ceased operating. 20 Please service the radio." Preferably, the serial number is printed visibly on the radio 102, so that an employee or repair technician is able to identify the malfunctioning unit via the serial number. Thereafter the base station 104 may query the user, asking whether the base station 104 should contact a repair service, as is depicted in operation 1002. For example, the display may prompt the user: "Would you like a service call 25 placed automatically?" The user responds via the input device 316. If the user responds negatively, the method terminates, as is depicted in operation 1004. If, on the other hand, the user responds in the affirmative, the base station 104 may look up contact information for a designated repair service corresponding to the sort of device determined to have malfunctioned, as is shown in operation 1006. Finally, in operation

1008, the repair service is contacted with the identity of the malfunction radio/auxiliary unit, and directions for scheduling repair. Operation 1008 may take on several forms. For example, the base station 104 may send an e-mail containing the aforementioned information. Alternatively, an alpha-numeric page may be sent. In principle, any form 5 of data transmission suffices. Further, in one embodiment of the present invention, a centralized service is notified of the malfunctioning radio/auxiliary device; the centralized service, in turn, contacts the appropriate repair service. The telephone network 110 or another network is used to contact the repair service. The service or other person that receives the message may call the business establishment at which the 10 base station 104 is located, to confirm that service is desired or to schedule an appropriate time for service.

FIG. 11 depicts an initialization scheme in accordance with one embodiment of the present invention. Execution of the method of FIG. 11 may occur during the initialization state 402 depicted in FIG. 4. As mentioned earlier, initialization is a 15 process by which the base station 104 communicates basic information needed by the two-way radio 102 for it to conduct communication. Additionally, the two-way radio 102 communicates its identity to the base station 104, so that it may be added to the list of radios to monitor for functionality. Initialization may occur in response to an IR communication link being established between the base station 104 and a particular 20 two-way radio 102. The two-way radio 102 may be configured to establish the IR communication link when it is powered on, if it is positioned sufficiently close to the base station 104 to allow IR communication. As depicted in FIG. 11, the initialization method commences by the base station 104 transferring to the radio 102 the carrier frequency upon which the radio is to transmit,  $F_1$ . This information may be transferred 25 to the radio via an IR link established using the IR interfaces 306 and 318. Next, in operation 1102, the carrier frequency upon which the radio 102 should expect to receive transmissions,  $F_2$ , is transferred to the radio. Of course, one skilled in the art recognizes that if a different radio network scheme were employed, a different set of initialization data would be transferred to the radio 102 to permit the radio 102 to properly

communicate with the network. For example, other information, such as the identity of a spreading code, or timing information regarding an open time slot may be transferred to the radio **102**, if necessary for communication with the network.

After receiving the information necessary for proper communication with the network, the radio **102** transfers to the base station information necessary for the base station **104** to monitor the functionality of the radio **102**. Specifically, in operation **1104**, the identification code that is to be embedded in transmissions from the radio **102** to the base station **104** is transferred to the base station. Next, in operation **1106**, the serial number of the radio **102** is transferred to the base station **104**. Finally, in operation **1108**, the radio **102** is entered into a list of radios to be monitored. This occurs by entering the serial number and identification code of the radio **102** into data arrays stored in the memory device **312**. The serial number and identification code are associated in such a manner that identification of one piece of information permits retrieval of the other. The initialization process typically is performed when a system is first installed, or when a new radio **102** is added to an existing system.

The various embodiments described above are provided by way of illustration only and should not be construed to limit the invention. Those skilled in the art will readily recognize various modifications and changes which may be made to the present invention without strictly following the exemplary embodiments and applications illustrated and described herein and without departing from the true spirit and scope of the present invention which is set forth in the following claims.